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FIRST DATA-DRIVEN APPROACH TO USING INDIVIDUAL CATTLE WEIGHTS TO ESTIMATE MEAN ADULT DAIRY CATTLE WEIGHT

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Dairy cattle, weight, automatic milking systems, antimicrobial usage, medicine dosing

Word count- 3156

ABSTRACT

Background

Knowledge of accurate weights of cattle is crucial for effective dosing of individual animals and for reporting antimicrobial usage. For the first time, we provide an evidence-based estimate of the average weight of UK dairy cattle to better inform farmers, veterinarians and the scientific community.

Methods

Data were collected for 2,747 lactating dairy cattle from 20 farms in the UK. Data were used to calculate a mean weight for lactating dairy cattle by breed and a UK-specific mean weight. Trends in weight by lactation number and production level were also explored.

Results

Mean weight for adult dairy cattle in this study was 617 kg (sd=85.6 kg). Mean weight varied across breeds, with a range of 466 kg (sd=56.0 kg, Jersey) to 636 kg (sd=84.1, Holsteins). When scaled to UK breed proportions, the estimated UK-specific mean weight was 620 kg.

Conclusion

This study is the first to calculate a mean weight of adult dairy cattle in the UK based on on-farm data. Overall mean weight was higher than that most often proposed in the literature (600 kg). Evidence-informed weights are crucial as the UK works to better monitor and report metrics to measure antimicrobial use and are useful to farmers and veterinarians to inform dosing decisions.

INTRODUCTION

Average weights of dairy cattle in the UK are not well defined. Scientific papers, reports and guidelines present a wide range of adult dairy cattle weights. A literature search demonstrated a range from 425 kg (EU estimated “average weight at time of treatment” (1)) to 680 kg (USA) (2) (Table 1). Additionally, the weights used in current literature are commonly either “estimated”, without clear evidence, or cited from another source (usually equally lacking in evidence). Average cattle weight would also be expected to vary with breed (3) and between populations (4) (e.g. countries, due to different compositions of herds nationally), but this is rarely accounted for in the literature.

Table 1

A selection of recent papers and reports using defined dairy cattle weights. Note that the majority of these weights have been defined for measuring antimicrobial usage.

Reference	Dairy cattle weight (kg)	Comments
Montforts, 2006 (5)	425	Not justified with a reference or data
ESVAC Methodology for Determining Antibiotic Use (1)	425	Average weight at time of treatment based on the assumption that younger animals are more likely to have antimicrobial treatment. Weights derived from a committee of European experts, citing (5). Cited widely in other literature.

UK-VARSS (6)	425	Average weight at time of treatment. Cites (1, 7). (Note, (7) actually gives a weight of 600 kg. It is assumed the correct citation is (5) – by the same author as (7)).
Carmo et al., 2017a, Carmo et al., 2017b (8, 9)	425	Assumption for the average weight of dairy cattle in Denmark and Switzerland at the time of treatment for use in AMU metrics. (1) cited in both papers.
Livestock Improvement Corporation Limited and DairyNZ Limited (10)	458	Average 'liveweight' for Holstein-Friesians in New Zealand. No reference presented.
Bryan and Hea, 2017 (11)	458	Assumption for the average weight of dairy cattle in New Zealand for use in AMU metrics. Cites (10).
Regula et al., 2009 (12)	400-500	Assumption for the average weight of dairy cattle in Switzerland for use in AMU metrics (no reference/data presented)
Grave et al., 2010 (13)	500	Considered a 'standard average' for all breeds of dairy cattle across 10 European countries for use in AMU metrics (no reference/ data presented)
Obritzhauser et al., 2016 (14)	500	Presented as '1 livestock unit'. Assumption for the average weight of dairy cattle in Austria for use in

		AMU metrics. Cites (15)
Montforts et al., 1999 (7)	600	No reference or data presented for weight values used
Jensen et al., 2004 (16)	600	Assumption for the average weight of dairy cattle in Denmark for use in AMU metrics where weights were “defined in consultation with [a] group of specialised practitioners”. Cited widely in other literature
Veterinary Antibiotic Usage and Resistance Surveillance Working Group, 2007, 2009 (17, 18)	600	AMU report for the Netherlands (“Monitoring of Antimicrobial Resistance and Antibiotic Usage in Animals in the Netherlands”). Cites (19)
Gonzalez et al., 2010 (20)	600	Assumption for the average weight of dairy cattle in Switzerland. Cites (16, 21) and Swiss breeding societies. Considered to be average weight at time of treatment
Merle et al., 2012 (22) & Merle et al. 2014 (23)	600	Assumption for the average weight of dairy cattle in Germany for use in AMU metrics. Cites (17)
Saini et al., 2012 (24)	600	Assumption for the average weight of dairy cattle in Canada for use in AMU metrics. Adult weight

		references (16) - Danish cattle; youngstock weights are not referenced.
Pereyra et al., 2015 (25)	600	Assumption for the average weight of dairy cattle in Argentina for use in AMU metrics. No reference/data presented.
Santman-Bereneds et al., 2015 (26)	600	Assumption for the average weight of dairy cattle in the Netherlands for use in AMU metrics as part of a model to predict mastitis incidence. No reference/data presented
Stevens et al., 2016 (27)	600	Assumption for the average weight of dairy cattle in Belgium for use in AMU metrics. Cites (16)
Kuipers et al., 2016 (28)	600	Assumption for the average weight of dairy cattle in the Netherlands. No reference/data presented
ANSES & ANMV, 2013 (29)	650	AMU report for France. Weights used are based on 'field experience'.
Pol & Ruegg, 2007 (2)	680	Assumption for the average weight of dairy cattle in the USA for use in AMU metrics. No reference/ data presented

Many medicine doses should be calibrated to the weight of the cattle being treated. Using incorrect weights may lead to incorrect dosing, which could prove ineffective or potentially dangerous. This is particularly true of antimicrobials where an underdose could fail to completely clear the infection, a problem which has been linked to the risk of resistance

developing (30). Additionally, metrics for reporting antimicrobial use (AMU, for example mg/kg or daily dose metrics (31)) commonly require the total weight of the animals at risk of treatment to be included in the calculation, giving a measure which accounts for the total kg.

The weight chosen will not specifically affect benchmarking if the farms being compared are using the same weight. However, if the included weight is too high or too low, this could lead to the metric under- or over-representing the actual use of the antimicrobials and confound comparison across farms or countries if different weights are used.

For the purpose of treating cattle with the appropriate dose of medicine, visually estimated weight is usually relied upon. However, it has previously been shown that visual estimates of cattle weights vary in accuracy compared with estimates from heart girth tape measurements, with under- and overestimation at the extremes of the weight scale (32). Visual estimates may also be influenced by expectations of weight, which can also vary widely. For example, we asked 15 farm vets in practices across South West England to estimate the average weight of a UK ‘Holstein-Friesian milking cow’, resulting in a range of 525-775 kg and a mean of 678 kg.

Additionally, weight estimates based on body measurements of cattle (e.g. Schaeffer’s formula (33)) or use of weigh tapes (34) have been shown to deviate from true weights (35). More accurate measures can be obtained from scales such as weigh crushes or weigh floors.

Some Automatic Milking Systems (AMS) have a weigh floor that records cattle weight at every milking (e.g. Lely, <https://www.lely.com/gb/>). These are predominantly used to monitor changes in weight and draw the stockperson’s attention to abnormal losses or gains (for example, Lely suggest a daily weight loss of 0.8% would require attention (36)). These

weigh floors have been used in previous studies to monitor cattle weight change over time (37, 38). They are precisely calibrated at installation and are cleaned and set to zero at every service (approximately 7 times over every 2-year period). Equipment is also widely available for weighing cattle through a handling crush.

This study used data collected from 20 UK farms (19 from farms using Lely AMS and 1 farm using a crush with weigh scales) in order to determine a mean UK adult dairy cattle weight for use by farmers, veterinarians and the scientific community. These data were also used to examine mean breed weights and to explore trends in weight by lactation number, days in milk and overall milk production.

MATERIALS AND METHODS

Data collection

Data were collected from 20 UK farms: 19 of these farms used Lely AMS and were recruited through Lely - 10 from Cornwall and Devon, 6 from Somerset and 3 from different areas of the UK. Lely emailed the farms from Devon, Cornwall and Somerset asking farmers to give permission to Lely to access the farm's AMS data for a single day (See Appendix). Data from the other 3 farms came from another study to which Lely had contributed. Farmers were asked to calibrate the AMS weigh floor scales ("calibrate" being the term used by Lely to describe the following: clean scales and remove any trapped stones, then select "tare scale" on the control screen) and contact Lely to let them know this had been done (by text message). Lely then remotely downloaded a report from the farm's AMS.

The 20th farm was recruited directly and cattle were weighed using a crush with a weigh bar and digital scales. This final farm was a Jersey herd in Devon and was included,

despite the different weighing method, for maximum representation across breeds. All cattle from the milking herd were weighed. An operator whose weight was known stood on the scales prior to use to check for accuracy, and the scales were set to zero between cattle if necessary.

Datasets from Lely were fully anonymised before they were received. For each animal, the dataset included her lactation number, days in lactation and milk produced that day as well as an average weight for her last 3 milkings of their current lactation. This average weight was used for all calculations. The dataset acquired using a crush was anonymised and contained lactation number, days in lactation and a single weight for each animal.

Individual animal breeds are not recorded by the Lely AMS and were instead assigned at the farm level by the farmer (and were predominantly Holstein, Friesian or Holstein-Friesian; Table S1). All farms were all-year-round calving which meant a full range of lactation stages were included.

Data cleaning

Farm datasets from Lely contained data for all milking cattle registered to that farm at the time the report was taken. This included the last weight and production measurements for cattle that had not been milked recently. Cattle not weighed recently were likely to be dry, therefore the measurement was likely to be from the end of their previous lactation; including these would have caused an over-representation of late lactation cattle. Additionally, extreme dates may have indicated that the electronic collars used by the AMS for identification may have been broken, or that the system was not updated to indicate that an animal was removed from the herd. Therefore, for each farm, data were only included from the date with the most

cattle milked/measured and the immediate week preceding (Table S1). Entries with missing weight or missing date were also removed; only 1 entry per animal was kept. At the Jersey farm, data were excluded if the scales were not set to zero in between cattle.

Representativity of data

To check that the cattle used in this study were representative of the UK herd, data were obtained on the proportion of heifers, mean lactation number and mean herd size. These data came from all UK herds that milk record with National Milk Records (NMR). The proportion of heifers in the NMR data was compared to the study sample using a chi-square test for equal proportions. As the herds included in the study dataset will be included in the herds provided by NMR, only simple comparisons were possible for mean lactation number and mean dairy herd size.

Data analysis

The distribution and descriptive statistics were calculated for mean weights of cattle for the following breed categories: Holstein, Friesian, Holstein-Friesian, Cross-breed, Jersey, Other breed. Weights were calculated overall (for all cattle) and split into first lactation only (heifers) and second lactation onwards (cows). Overall mean weights and heifer and cow weights were compared across breeds using t-tests. Mean weights of heifers and cows for each breed and for the dataset as a whole were also compared using t-tests.

Additionally, the mean weight for cattle in each day of lactation (overall and split into heifers and cows) was calculated and plotted to identify any trends over lactation. Only cattle within 407 days lactation were plotted: this is the median calving interval according to NMR (39). The correlation between mean weight and daily milk production was calculated. As milk

production is known to vary across lactation, this analysis was repeated with only cattle considered to be in peak production (20-60 days into lactation).

Data analysis and graphics were generated using the statistical computing package R (<https://www.r-project.org/>).

Estimated average weight for the UK

By comparing the proportion of each breed within this dataset to the proportion in the UK population (using data provided by the British Cattle Movement Service (BCMS), Table S2), an estimated average adult dairy cattle weight for the UK was calculated. Breeds reported by BCMS were grouped into categories (Table S2 & S3) aligned with the breeds for the study data. To estimate a UK national average weight, mean weights by breed category calculated from the study data were scaled according to the representation of that category within the BCMS data.

Calibration checks

For each farm using Lely AMS, the distribution of weights for each of the farm's individual AMS units was calculated and checked for any unexpected deviation from the overall mean for that farm and breed using t-tests. Additionally, we collected 6 days of weight data directly from the farmer from the largest farm (with the highest number of AMS units) over a 1-week period. These data were used to check the calibration accuracy of the individual weigh floors by comparing the mean and distribution of weights each day using t-tests.

RESULTS

Data description

The original datasets included 3,106 cattle; after cleaning, 2,747 cattle remained (i.e. 11.5% of cattle were excluded due to dates outside of range, missing date or weight information (Lely) or if the scales were not set to zero before weighing (Jersey farm)). Table 2 presents summary statistics for the cattle included in the study. Just under a third of cattle were in their first lactation. On the date of sampling, mean production was 33 L (Table 2).

Table 2

Summary data for 20 farms and 2,747 cattle remaining after cleaning for date and missing data was performed

Breakdown of cattle		N (%)
Total farms		20
By breed*	Holstein	7 (35.0%)
	Friesian	2 (10.0%)
	Holstein-Friesian	8 (40.0%)
	Jersey	1 (5.0%)
	Cross-breed	1 (5.0%)
	Other	1 (5.0%)
Total cattle		2,747
By breed*	Holstein	1,099 (40.0%)

	Friesian	130 (4.7%)
	Holstein-Friesian	1,099 (40.0%)
	Jersey	170 (6.2%)
	Cross-breed	197 (7.2%)
	Other	52 (1.9%)
By lactation number	1 (heifers)	857 (31.2%)
	2+ (cows)	1,890 (68.8%)
Summary statistics of key properties		Mean (sd)
	Number of cattle per farm**	137.3 (sd=74.9)
	Lactation number	2.7 (1.8)
	Days in milk	174.3 (116.2)
	Production data (litres)***	32.7 (11.2)

*Note that breed is assigned at farm level.

**Note this is a mean across farms after some cattle were removed due to cleaning, actual mean herd size was 155 (cows currently in milk only)

***Production data was not available for the Jersey cattle

Representativity of data

Data provided by NMR on all dairy cattle in UK herds indicated that the mean proportion of heifers within a herd nationally was 29.1% (95% CI [29.0%, 29.2%]), compared

to 31.2% (95% CI [29.5 %, 33.0 %]) within the study dataset (Table 2). The mean lactation number within herds nationally was 2.8, compared to 2.7 within the study dataset (Table 2). The mean number of cows in milk per herd was the same nationally as in the study dataset (155; the mean number of cows with usable data was 137 per herd; Table 2).

Data analysis

The cattle within the study dataset had an overall mean weight of 617.3 kg (standard deviation 85.6 kg, median 620 kg) across all breeds and including both heifers and cows (Table 3). Heifers were on average 9.0% lighter than cows (Figure 1A) with mean weight 578.0 kg for heifers and 635.2 kg for cows (t-test: $P < 0.05$). Jersey cattle were 25.8% lighter than the overall mean weight for all other breeds (465.7 kg compared to 627.3 kg).

Table 3

Summary of mean weights of breeds represented. Note that breed is assigned at farm level. A t-test was used to compare the mean weights of heifers and cows.

Breed	N (%)	Overall mean weight, kg (sd)	Heifers mean weight, kg (sd)	Cows mean weight, kg (sd)	<i>P</i>- value
Holstein	1,099 (37.9%)	636.1 (84.1)	583.9 (73.7)	668.1 (73.5)	<0.001
Friesian	130 (13.9%)	629.3 (65.9)	586.7 (82.3)	636.1 (60.6)	0.024
Holstein- Friesian	1,099 (26.9%)	617.4 (72.8)	590.9 (66.1)	627.1 (72.8)	<0.001

Jersey	170 (22.4%)	465.7 (56.0)	407.1 (41.9)	482.6 (47.6)	<0.001
Cross-breeds*	197 (37.6%)	623.1 (64.3)	570.7 (47.0)	654.6 (51.4)	<0.001
Other **	52 (26.9%)	662.8 (65.8)	618.4 (56.6)	679.1 (61.8)	0.003
Excluding Jersey	2,577 (31.8%)	627.3 (77.4)	585.9 (69.1)	646.6 (75.0)	<0.001
Overall	2,747 (31.2%)	617.3 (85.6)	578.0 (77.4)	635.2 (83.2)	<0.001

*cattle recorded as cross-breed

**consisting of different breeds, predominantly dual-purpose breeds

Effect of breed, lactation number, days in milk and production

Some variations in overall mean weight across breeds was seen within the dataset (Table 3, Figure 1B, Figure S1). Of the named breeds, Holstein were the heaviest (636.1 kg) and Jersey the lightest (465.7 kg). Cattle categorised as “Other” were heavier than all breeds (662.8 kg, $P < 0.01$, Table S4), however the dataset contained a very low number in this category ($n=52$, all from 1 farm) and they were predominantly dual-purpose breeds which would be expected to be heavier.

The proportion of heifers varied between breeds in this dataset. For example, just over 10% of Friesians were heifers, whereas almost 40% of Holsteins were heifers (Figure S2).

Heifers were on average 9.0% lighter than cows. This is likely to skew the means; indeed, the variation between mean weight of Holstein and Friesian cows was far greater, whereas there was almost no difference between the heifer means for these breeds (Figure 1B, Table S4).

Average weight increased by lactation number until lactation 3 (Figure S3) and was similar across lactations 3, 4 and 5. Beyond lactation 5, average weight declined although the number of cattle represented within these later lactations was limited.

There was no correlation between weight and milk production for the 19 Lely farms (production data was unavailable for the Jersey farm) using all cattle (Figure S4A). However, when including only cattle at peak production (days 20-60), cattle with greater production were heavier (Figure S4B).

Mean weight of cattle grouped by day of lactation declined for the first 30 days post-calving and was then seen to rise steadily for the remainder of the lactation (Figure 1C). However, the number of cattle at each day was low, giving wide confidence intervals to these trends. Heifers had a consistently lower weight across lactation than cows.

Estimated average weight for the UK

Taking the mean weights for different breeds in the study dataset (Table 3) and the distribution of these breeds within the UK dairy population (Table S5), a UK average weight was calculated as 619.6 kg.

Calibration checks

No substantial differences in the mean weight between robots on farms (and hence by breed) were found once proportions of heifers and cows milked by that robot on the day of data collection were accounted for (data not shown to preserve anonymity).

There was little variation in the mean weight for the 6 days of data collected from the single large farm (Figure S5). None of the daily distributions were significantly different from each other ($P>0.7$) indicating that the calibration of robots was likely to be accurate; significant deviations in weighings from a single robot would affect the distribution and mean weight for that day and would be detected by t-tests (as well as being flagged by the system on farm).

DISCUSSION

The overall mean weight for all 2,747 dairy cattle was 617.3 kg. Scaling by UK breed proportions gave an estimated average weight for adult UK dairy cattle of 619.6 kg. It is therefore suggested that a national-level weight of 620 kg to be used for AMU calculations, with farm-level weights to be estimated based on the breed mix on the farm. The most commonly assumed dairy cattle weight in the literature was 600 kg. The data presented here suggests that 600 kg is likely to be an underestimation of mean adult dairy cattle weight in the UK.

The impact of having an evidence-based figure for average weight as well as variation by breed, production level and days in milk will be marked. For dosing, visual weight estimation of individual cattle will be easier and more accurate if an actual average is known in the first instance, allowing more accurate calibration of medicine doses (Figure 2A). Also, for national-level antimicrobial use reporting, a recommended UK weight of 620 kg will be

invaluable, as using too high or too low a weight can significantly impact calculations of antimicrobial use (Figure 2B).

Grouping cattle by day of lactation indicated an initial decline in mean weight, followed by a steady increase. These results support trends reported in the literature for both body weight and body condition scores (40, 41). This trend is consistent with the expected period of negative energy balance and the mobilisation of body fat a dairy cow is likely to experience following calving (42). However, the difference in mean weight over lactation is not marked enough to support any additional adjustment in weight estimate before medicine dosing, for example. Further work looking at repeated measures for a large sample of cattle (and breeds) across the lactation period would confirm these trends.

There was some variation in weight distribution across all breeds included in this study, ranging from 465.7 kg (Jersey) to 636.1 kg (Holstein). The variation observed between breeds was confounded by differences in the proportions of heifers and cows in each breed. For example, when heifers were removed, the difference in weight between Holstein and Friesian cows widened, though heifers in both breeds had very similar weights.

It is noted that breeds in this dataset were assigned at the farm level, so it is possible that there was within-farm variation which could not be accounted for. By contrast, the BCMS data used individual animal breed counts but could not be split by heifer or cow status. Therefore, breed was unable to be used with heifer/cow ratios in the UK average weight calculation. As heifers weigh less than cows, this could mean the UK average weight was underestimated, as the sample had a slightly higher proportion of heifers than the NMR data (31.2% compared to 29.1%). Furthermore, only one Jersey farm was represented within this

dataset. Ideally multiple farms which reflect the varying types of Jersey cattle would have been included in order to better represent this breed. With breeds assigned at farm level, there is also likely to be some overlap amongst black and white breeds; for example a herd described as 'Holstein-Friesian' may actually comprise of a mixture of Holsteins, Friesians and Holstein-Friesians.

This study looked exclusively at lactating cattle due to the limitations of the methods employed. It is noted that dry cows are likely to be heavier than lactating cows (42) and thus the weights presented in this paper may be an underestimation. However, we note that the average weight presented - even if an underestimation - is still higher than the weights currently being used for AMU metrics.

There was variation in weight by different lactation numbers, with the highest average weight seen for lactations 3, 4 and 5. This was, however, unlikely to affect the overall average weight as the average number of lactations in this dataset (2.7) was comparable to the national average (2.8) (39).

Despite these limitations, the 620 kg national-level mean weight is the most accurate figure to use at national and farm levels for calculating AMU metrics. However, it is noted that when benchmarking farms against each other, it will be important to consider the impact that the breed and heifer/cow ratios may have on individual farm AMU figures. At the individual animal level, veterinary practitioners would be expected to calibrate medicine doses according to this average weight, but with further adjustments if needed for animal breed and age using the presented breed results as a guide only. Further studies with larger sample sizes are needed to confirm mean weights by breed.

If farms using Lely AMS differed from the average dairy farm, this could create a

selection bias. However, the Lely AMS farms used demonstrated a wide variety of management practices and type of cow. The Lely farm animal support advisors were confident that the majority of AMS farms used a 'standard' type of dairy cattle, and also stated that many of the farms are flying herds and buying in 'standard black and white' cattle as replacements from UK markets. Though there are Jersey farms using Lely AMS which were asked for data, these farms did not record weights. 2.2% of UK cattle are Jersey cattle, which are smaller and lighter than the rest of the UK national herd, hence it was important to represent them accurately. This was only possible using an alternative, non-Lely AMS farm, which was weighing cattle using a weigh crush.

Lely robots are calibrated precisely at installation only but are regularly serviced and farmers are advised to regularly clean and tare the weigh floor. This regular cleaning by Lely and the farmer should ensure inaccuracies are minimal. During data collection for this project, farmers were asked to calibrate the scales. The normal distribution of the data indicates that there were no major inaccuracies unless identical inaccuracies were occurring on every farm in the dataset, which seems unlikely. Indeed, data obtained over a week from a single farm showed no significant difference in mean weight between days.

To confirm and expand on the estimated weights presented here, future studies should increase sample size for each breed, add data from other breeds and include other areas of the UK and farms not using Lely AMS. It would also be of interest to explore weights for bulls and youngstock.

This study is the first to estimate a mean weight of UK dairy cattle based on data. Weights from 2,747 cattle from the 4 main named breeds, as well as cross -breeds and less

common breeds were considered. These data provide valuable evidence to support 620 kg as an appropriate average weight of UK adult dairy cattle for use in AMU benchmarking and as a guide for medicine dosing.

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FIGURE LEGENDS

Fig 1: A: Overall distribution of all weights, split into heifers (red) and cows (blue). Mean weights were 578.0 kg for heifers and 635.2 kg for cows, marked with a red triangle and blue square respectively. B: Box plots of the weights of different breeds with heifers (red, left) and cows (blue, right) separated. Heifers were lighter than cows for all breeds ($p < 0.05$, Table 3). C: Mean weight for cattle grouped by day lactation (black circles, with black lines indicating

95% confidence intervals), and for only heifers (red triangles) and only cows (blue squares). Note that confidence intervals are calculated assuming a normal distribution. Points are filled if there are more than 10 cattle at that lactation point, otherwise points are unfilled. Only cattle within 407 days of lactation were included (the median calving interval for Holstein-Friesian herds in 2016 (39)).

Fig 2: Illustration of the effect different assumed cattle weights can have on the medicine dose for Holstein-Friesians (panel A) and effect on the resulting mg/kg metric when measuring antimicrobial use in dairy cattle (panel B). In panel A, 525 and 775 kg weights were the lowest and highest estimates from practising veterinarians asked to estimate the average weight of a UK Holstein-Friesian milking cow, 600 kg was the most common adult dairy cattle weight reported (Table 1), and 617 kg was the mean weight of Holstein-Friesians estimated in this work. In panel B, note that a usage of 16×10^9 mg of antimicrobial in the UK is intended as an example only. 425 kg was the lowest dairy cattle weight reported in the literature (as the “estimated weight at time of treatment” (European Surveillance of Veterinary Antimicrobial Consumption (1))), 600 kg was the most common weight reported (Table 1), 620 kg was the UK mean weight estimated in this work and 680 kg was the most extreme weight reported in the literature (Table 1, note this weight was from the USA as reported by Pol and Ruegg, 2007 (2)).